

SELECTIVE FILE PURGING FOR DELETE OR RENAME**Technical Field**

The present invention relates to remote file access, and more specifically to purging delayed file closes before a remote file delete or file rename operation is performed.

Background of the Invention

Efficient and secure information transfer between computers over a computer network has become a paramount concern in most every corporate and educational organization today. A key element to efficient and secure information transfer is the network file system employed by modern computers. A network file system manages file sharing between computers requesting data ("clients") and computers supplying the data ("servers"). A central goal in computer network design issue is increasing network file system performance without compromising the integrity of the network.

One of the most performance costly operations carried out by network file systems is a file open operation. A file open request is typically issued by a client before any file access is granted by a server. During the file open operation, the client and server perform time-consuming handshaking, negotiating, and security verification procedures to ensure network integrity is maintained. If an application repeatedly opens and closes the same remote file in quick succession, the overhead penalty of each open operation can significantly degrade network system performance.

To minimize the overhead penalty of repeated open requests, network file systems typically delay closing open files for several seconds in the event an application will quickly re-access the same file again. Stalling a file close command is also referred to herein as caching file opens or caching an open file. Broadly speaking, the file system records the filenames of cached open files in a delayed close list (also known as a scavenger list) and waits until a timeout occurs. Unless the application issues another open request for the remote file, the close file command is sent to the remote server after the timeout and the file reference is deleted from the

delayed close list. However, if the same application quickly follows a close request with a file open request for the same remote file, the file system disregards the application's earlier close command. To the server, it appears as though the client never closed the file between file accesses. Thus, caching file opens helps the network file system avoid repeated file open operations by consolidating successive remote file accesses.

One problem associated with delaying file closes occurs when a delete or rename operation is requested for an aliased file. Aliased files have two or more filenames that refer to the same file. Generally, file aliasing exists in operating systems which support file access using both a FAT32 or NTFS filename (long filename) and a FAT16 filename (short filename or 8.3 filename). In such operating systems, a remote file may be opened using either its long filename or its short filename.

The problem arises when a client issues a file delete command or a file rename command shortly after issuing a file close command for the same remote file using different names for the same file. From the client's perspective, the two commands should be carried out without trouble since the file is closed before the delete or rename command is sent to the remote server. As discussed above, however, the network file system delays sending the file close command to the server to improve system performance and, unless corrected, the delete command will be sent to the server before the close command. From the server's perspective, a file sharing violation is created when the client tries to delete a file before closing it. Complicating the matter even further is the fact that the close command and the delete/rename command use different filenames to identify the same remote file. Thus, the network file system cannot discover or prevent the conflicting operations by searching the delayed close list for the same filenames.

One known solution to this problem is to aggressively purge all files from the delayed close list that may potentially cause a file sharing violation to occur whenever a remote file delete or remote file rename command is received by the network file system. Thus, when a remote file delete/rename command is issued by an application, all potential file aliasing candidates in the delayed close list are quickly closed regardless of a timeout occurrence before the delete/rename command is sent to the remote server. For example, when a client requests a

remote file to be deleted, the network file system closes all files in the delayed close list with the same server name and share name as the remote file, even though their filenames and/or directory names may differ. This approach ensures that any cached open file that potentially aliases the file to be deleted or renamed is closed before the delete/rename command is issued to the remote server.

One drawback of the above approach is that a large number of casualty files not aliasing the delete or rename command filename are typically purged from the delayed close list unnecessarily. When the client subsequently tries accessing these casualty files, the network file system must reopen these files using the costly file open operation. Thus, system performance is degraded when casualty files are purged from the delayed close list to prevent server sharing violations.

Summary of the Invention

The present invention overcomes the above-mentioned shortcomings of network file systems by referencing a unique file identifier (FID) in the delayed close list. The unique FID always identifies the same remote file regardless of the filename used. In one embodiment of the invention, when a remote target file is to be deleted or renamed, the network file system obtains the target file's unique FID from the server's file management system. The network file system then purges only those files in the delayed close list whose unique FID matches the unique FID of the target file. Files in the delayed close list whose unique FIDs do not match the target file's unique FID are left open. In this manner, casualty files are eliminated and system performance is greatly improved.

Accordingly, one aspect of the present invention is a method for purging cached open files from a delayed close list which reference a target file located on a remote server. The cached open files include cached filenames and the target file includes a target filename. The method includes a storing operation for storing a unique file identifier for each of the cached files. Furthermore, the unique file identifier is independent of the cached filenames. A receiving operation receives a target file identifier for the target file from the server, wherein the target file

identifier is independent of the target filename. The method also includes a purging operation that purges from the delayed close list the cached open files having the same unique file identifier as the target file identifier.

In accordance with other aspects, the present invention relates to a computer-readable medium having stored thereon a data structure for purging a delayed close list of cached open files. The data structure includes a namespace field representing a network filename for a remote file, and a unique file identifier independent of the network filename.

Another aspect of the present invention is a computer program product readable by a computing system and encoding a computer program of instructions for executing a computer process for purging a cached open file from a delayed close list which references a target file located on a server. The computer process includes storing a file namespace and a unique file identifier for the cached open file, wherein the unique file identifier is independent of the file namespace. A receiving operation receives a target namespace and a target file identifier for the target file. Likewise, the target file identifier is independent of the target namespace. The computer process includes purging from the delayed close list the cached open file if the cached open file has the same unique file identifier as the target file identifier.

These and various other features, as well as advantages, which characterize the present invention, will be apparent from a reading of the following detailed description and a review of the associated drawings.

Brief Description of the Drawings

Fig. 1 shows the basic functional units of a computing device implementing various embodiments of the present invention.

Fig. 2 illustrates a representation of a typical computer network system utilizing an embodiment of the present invention.

Fig. 3 shows a more detailed functional diagram of a client-side remote file system as contemplated by the present invention.

Fig. 4A shows a representation of the file handle table as contemplated by the present invention.

Fig. 4B illustrates two file control blocks referencing the same remote file using different filenames while maintaining the same unique file identifier.

Fig. 5 shows a control flow diagram contemplated by the present invention for purging entries in a delayed close list.

Detailed Description of the Invention

The invention is described in detail below with reference to the figures. When referring to the figures, like structures and elements shown throughout are indicated with like reference numerals.

The present invention involves referencing a unique file identifier (FID) to more efficiently handle cached open files on a network file system. Techniques for caching open files on network file systems are well known and are beneficially used in conjunction with the present invention. However, the present invention incorporates a unique FID field to remote file references and allows for more rigorous file identification of cached open files on delayed close lists.

In **Fig. 1**, the basic functional units of a computing device **102** implementing various embodiments of the present invention are shown. Thus, particular embodiments discussed herein may be realized using a general-purpose computer. However, it is expressly understood that the inventive features of the present invention may be usefully embodied in a number of alternative processor architectures that will benefit from the performance features of the present invention. Accordingly, these alternative embodiments are equivalent to the particular embodiments shown and described herein.

Fig. 1 shows a typical computing device **102** incorporating a general-purpose processor **104** in accordance with an embodiment of the present invention. The computing device **102** comprises an address/data bus **106** for communicating data and control information, at least one

processor **104** coupled with the bus **106** through an input/output (I/O) interface **108**, and a memory system **110** coupled with the processor **104** for storing information and instructions. The memory system **110** includes, for example, cache memory **112** and main memory **114**. Cache memory **112** includes one or more levels of cache memory. In a typical embodiment, the processor **104**, I/O interface **108**, and some or all of cache memory **112** may be integrated in a single integrated circuit, although the specific components and integration density are a matter of design choice selected to meet the needs of a particular application.

User I/O devices **116** are coupled to the bus **106** and are operative to communicate information in appropriately structured form to and from the other parts of the computer **102**.

User I/O devices **116** may include a keyboard, mouse, card reader, magnetic or paper tape, magnetic disk, optical disk, or other available input devices, including another computer. A mass storage device **118** is coupled to the bus **106** and may be implemented using one or more magnetic hard disks, magnetic tapes, CDROMs, large banks of random access memory, or the like. A wide variety of random access and read only memory technologies are available and are equivalent for purposes of the present invention. The mass storage **118** may include computer programs and data stored therein. In addition, some or all of the mass storage **118** may be configured to be incorporated as a part of the memory system **110**.

In a typical computing device **102**, the processor **104**, I/O interface **108**, memory system **110**, and mass storage device **118**, are coupled to the bus **106** formed on a printed circuit board and integrated into a single housing as suggested by the dashed-line box **120**. However, the particular components chosen to be integrated into a single housing are based upon market and design choices. Accordingly, it is expressly understood that fewer or more devices may be incorporated within the housing suggested by dashed line **120**.

Display device **122** is used to display messages, data, a graphical or command line user interface, or other communications with the user. Display device **122** may be implemented, for example, by a cathode ray tube (CRT) monitor, liquid crystal display (LCD) or any available equivalent.

10 A communication interface **124** is utilized for carrying out digital or mixed analog-digital communications with other electrical devices over a network. The communication interface **124** may carry out wire based communications and/or wireless communications. Various communication protocols may be supported by the communication interface **124** including, but not limited to, Transmission Control Protocol/Internet Protocol (TCP/IP), and Common Internet File System (CIFS) protocol. Of particular importance to the present invention, the communication interface **124** allows the computer device **102** to access remote files stored on servers by means of a network file system.

15 As used herein, a network file system refers generally to a mechanism responsible for file access between clients and servers over a computer network. The network file system is typically a service or component of a network operating system, such as the Microsoft(R) Windows NT(R) operating system. Microsoft and Windows NT are registered trademarks of Microsoft Corporation.

20 In Fig. 2, a representation of a typical computer network system **202** utilizing an embodiment of the present invention is shown. The network system **202** may be implemented on a local area network (LAN) or a wide area network (WAN). Furthermore, LANs may be implemented using any available topology such as a hub and spoke topology and a loop topology. During discussions of embodiments of the present invention, a client-server network arrangement is referred to and illustrated. It should be noted, however, that other conventional network arrangements, such as a peer-to-peer network arrangement, may be utilized in connection with the present invention.

25 The computer network system **202** consists of a client **204** communicating with a server **206** through a network **208**. The client **204** includes at least one application **210** executed under a client-side operating system **212**. Typically, the application **210** is executed under a non-privileged processor mode (referred to as "User Mode") and is given only limited system access through the operating system **212**. The operating system, on the other hand, is run under a privileged processor mode (referred to as "Kernel Mode") and is given full system access to memory and processor commands.

When the application **210** requires access to a remote file **214**, it sends a remote I/O request through the operating system **212** to an I/O manager **216**. The I/O manager **216**, in turn, passes remote I/O requests to the client-side remote file system **218** for further processing. The remote file system **218** accepts and translates the I/O request into network file system protocol commands that are sent to a server-side remote file system **220**.

The server-side remote file system **220** listens for commands coming from the network **208** and issues the I/O request to a local file system **222**. The local file system **222** carries out the I/O request by interfacing with a device driver **224** that manages the volume **224** on which the remote file **214** or directory that the I/O command is intended for resides.

In Fig. 3, a more detailed functional diagram of one embodiment of a client-side remote file system **218** contemplated by the present invention is shown. The remote file system **218** includes a command interface **302** coupled with the I/O manager **216**. The command interface **302** is configured to exchange remote I/O messages between the I/O manager **216** and a file system controller **304**. The command interface **302** may also interact with a cache manager (not shown) to cache server file data on the client system.

The file system controller **304** manages various aspects of remote file access, such as server negotiation, cache coherency, security verification, and data formatting. In one embodiment of the present invention, the file system controller **304** is coupled with an CIFS interface **306**. The CIFS interface **306** packages data sent from the client to a remote server according to the CIFS protocol. Additionally, the CIFS interface **306** translates CIFS formatted data received from remote servers and passes it to the file system controller **304**.

The file system controller **304** maintains a file handle table **310** listing handles of remote files accessed by the client. Each file handle in the file handle table **310** points to a file control block (FCB), thereby allowing the file system controller **304** to quickly identify an opened remote file. Furthermore, each FCB incorporates file objects containing access information about the remote file and its server.

With reference now to **Fig. 4A**, a representation of the file handle table **310** is shown. As mentioned above, the file handle table **310** includes a plurality of remote file handles **402** pointing to FCB **404** structures. The FCB **404** may include such fields as a server ID **406**, a session ID **408**, and a file namespace **410** of the associated remote file. In accordance with 5 embodiments of the present invention, the FCB **404** also includes a unique FID **412** which is independent of the file namespace **410**. In one embodiment of the present invention, the unique FID **412** is a 64-bit universal file ID supplied by an NTFS file system.

The unique FID **412** is used to match FCBs referencing the same remote file using different file namespaces. For example, one FCB may reference a remote file by its long (FAT32) filename and another FCB may reference the same remote file by its short (FAT16) 10 filename. Such an example is illustrated in **Fig. 4B**, where a first FCB **414** and a second FCB **416** having different file namespace entries reference the same remote file **418**. The remote file **418** is named My_Document.doc, however, it is also aliased as MY_DOC~1.DOC to ensure compatibility with the FAT16 file system format. Accordingly, the namespace field **420** of the first FCB **414** contains the long filename format, while the namespace field **422** of the second FCB **416** contains the short filename format. Nevertheless, both FCBs **414** and **416** refer to the same remote file **418** and contain the same unique FID value (64-bit) in their respective unique FID fields **424** and **426**. 15

Returning to **Fig. 3**, when an application no longer requires access to a remote file, it 20 typically issues a close command to the I/O manager **216**. The command interface **302** intercepts the close command and passes it to the file system controller **304**. The file system controller **304** then checks whether other executing applications are accessing the remote file. If no other application is accessing the remote file, the file system controller **304** removes the remote file's handle from the file handle table **310** and places the handle in a delayed close list **312**, thereby 25 caching the file open.

In addition to caching the file open on the delayed close list **312**, the file system controller **304** creates a scavenge thread **314** which counts down a brief time delay. The time delay is typically between 2 to 5 seconds, and may be adjusted to optimize system performance.

If, during the time delay, an open command corresponding to a file cached in the delayed close list **312** is received by the command interface **302**, the file system controller **304** removes the file handle from the delayed close list **312** and restores the handle in the file handle table **310**. In doing so, remote file access overhead is reduced by eliminating repeated open commands. If, on the other hand, the remote file is not accessed again before the timeout delay completes, the file system controller **304** sends a close command to the file server via the CIFS interface **306** and the file handle entry is removed from the delayed close list **312**.

To prevent network sharing violations, as discussed earlier, the client must ensure that a remote target file is not cached on the delayed close list **312** before the client attempts to delete or rename the target file. In one embodiment of the present invention, the file system controller **304** ensures all entries referencing the remote target file are purged from the delayed close list **312** before deleting or renaming the target file. This is achieved by comparing the recorded unique FIDs of all the entries in the delayed close list **312** with the unique FID of the target file. Hence, any delayed close list entry containing a unique FID matching the target file's unique FID is expressly closed and removed from the delayed close list **312**. By utilizing the unique FIDs of delayed close list entries, only those entries aliasing the remote target file are purged from delayed close list **312**. Therefore, the present invention greatly reduces the inefficiencies of aggressive prior art purging techniques which remove non-target related entries from the delayed close list **312**.

In **Fig. 5**, a control flow diagram contemplated by the present invention for purging entries in a delayed close list **312** is shown. The control flow begins at receiving operation **502** wherein the client-side remote file system **218** receives a command from an executing application **210** to delete or rename a remote target file **214**. As described above, remote I/O commands may be issued through an I/O manager **216** and intercepted by a command interface **302** in the remote file system **218**. Once the delete or rename command is received by the remote file system **218**, control passes to querying operation **504**.

In querying operation **504**, the client **204** queries the server **206** for the unique FID **412** of the target file **214**. The unique FID **412**, as earlier mentioned, is a value assigned to the target

file **214** which is independent of the filename used to identify the target file **214**. The FID is obtained when the file is opened. Thus, the same unique FID **412** is returned to the client **204** whether the client **204** uses a FAT16 filename or a FAT32 filename to identify the target file **214**. Once the target file's unique FID **412** is received from the server **206**, control proceeds to operation **506**.

In operation **506**, the file system controller **304** prepares to examine all delayed close list entries for matching unique FIDs by setting the first delayed close list entry as a next delayed close list entry. Control then passes to comparing operation **508**.

In comparing operation **508**, the remote file system **218** compares the unique FID of the next delayed close list entry to the unique FID of the remote target file **214**. Beginning with the first delayed list entry, the comparing operation **508** tests the next delayed close list entry each time it is invoked. Once the next delayed close list entry is examined, control transfers to branching operation **510**.

In branching operation **510**, the result from comparing operation **508** is examined. If the unique FIDs of the next delayed close list entry and the remote target file matched in comparing operation **508**, this indicates that the next delayed close list entry is referencing the target file **214** and must be purged from the delayed close list **312** before the delete or rename command is issued to the server **206**. Thus, the branching operation **510** passes control to closing operation **512**.

In closing operation **512**, the remote file referenced by the next delayed close list entry (i.e. the target file) is closed by client **204**. In a particular embodiment of the present invention, the CIFS interface **306** issues a file close command to the server **206** over the network **208**. Next, control is passed to deleting operation **514**, where the next delayed close list entry is deleted from the delayed close list **312**.

After deleting operation **514** is executed, or if the unique FIDs of the next delayed close list entry and the remote target file did not match in comparing operation **508**, control passes to branching operation **516**. In this operation, the remote file system **218** determines if all the

delayed close list entries have been examined. If more entries in the delayed close list **312** need to be compared with the unique FID of the target file **214**, control loops back to comparing operation **508**. If, on the other hand, every delayed close list entry has been examined, control branches to issuing operation **518**.

5 When the control flow reaches issuing operation **518**, all delayed close list entries referencing the remote target file **214**, whether by the target file's long filename or its aliased short filename, have been purged from the delayed close list **312**. Thus, the client issues the delete or rename command received in operation **502** to the server **206** without causing a file sharing violation.

10 It should be recognized by the reader that the logical operations of the various embodiments of the present invention described above may be implemented (1) as a sequence of computer implemented steps or program modules running on a computing system and/or (2) as interconnected machine logic circuits or circuit modules within the computing system. The implementation is a matter of choice dependent on the performance requirements of the computing system implementing the invention. It will be recognized by one skilled in the art that these operations, structural devices, acts and modules may be implemented in software, in firmware, in special purpose digital logic, and any combination thereof, without deviating from the spirit and scope of the present invention as recited within the claims attached hereto.

15 Although the invention has been described in language specific to computer structural features, methodological acts and by computer readable media, it is to be understood that the invention defined in the appended claims is not necessarily limited to the specific structures, acts or media described. As an example, the unique FID field **412** may be included in the session ID field **408**. Therefore, the specific structural features, acts and mediums are disclosed as exemplary embodiments implementing the claimed invention.

20 The various embodiments described above are provided by way of illustration only and should not be construed to limit the invention. Those skilled in the art will readily recognize various modifications and changes that may be made to the present invention without following

the example embodiments and applications illustrated and described herein, and without departing from the true spirit and scope of the present invention, which is set forth in the following claims.